THE STAR FORMATION NEWSLETTER

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From the Editor

Several problems conspired to make the e-mail connection to La Silla unreliable over the holidays. Should it have happened that you have sent an abstract to me, which does not appear in this issue, kindly send it once more to me. Happy New Year to everybody.

Abstracts of recently accepted papers

IRAS Pointed Observations Data Processing

R. Assendorp[1] **and P.R. Wesselius**[1]

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We have developed a system to process raw IRAS Pointed Observation (PO) data, using software developed at the Laboratory for Space Research, Groningen, The Netherlands. Several PO's can be coadded into one image. As an example we processed 99 PO's in the Chamaeleon I molecular cloud into one image for every IRAS band. The list of extracted point sources contains some 300 new IRAS sources, down to a flux level of 21 mJy at 12 μ.

Accepted by Astron. & Astrophys. Suppl.

Collapse and Fragmentation of Molecular Cloud Cores. I. Moderately Centrally Condensed Cores

Alan P. Boss

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The high frequency of detection of binary companions to pre-main-sequence stars and suspected protostars supports the hypothesis that binary stars are formed through the fragmentation of collapsing molecular cloud cores. Observations show that molecular cloud cores are centrally condensed, typically prolate in shape, and often contain significant angular momentum. A second-order accurate radiative hydrodynamics code has been used to calculate the self-gravitational collapse of protostellar clouds with initial properties similar to the observed molecular cloud cores. The initial clouds have exponential density profiles, with central densities a factor of 20 higher than the boundary density, and uniform angular velocity. Exponential density profiles are flatter at the center and steeper in the outer regions than the power law profiles used to model molecular cloud cores. Depending on the initial ratios of thermal (α_i) and rotational (β_i) to gravitational energy and the initial axis ratio, such clouds may either: (a) collapse to slightly higher densities and then re-expand to a diffuse, ellipsoidal equilibrium state, (b) collapse toward stellar densities while retaining a single density maximum, or (c) collapse and fragment into a binary or higher order system of protostellar cores moving on highly eccentric orbits. For a 2:1 initial axis ratio, the critical values are about $\alpha_i < 0.54 - 0.42\beta_i$ for (b) to occur and $\alpha_i < 0.45 - 0.36\beta_i$ for (c), while for a 1.5:1 initial axis ratio, the values are $\alpha_i < 0.62 - 0.48\beta_i$ for (b) and $\alpha_i < 0.33 - 0.26\beta_i$ for (c). These critical values for α_i are significantly lower than those derived by Miyama,

Hayashi, & Narita (1984) for initially uniform density clouds, indicative of the increased resistance to fragmentation in centrally condensed cloud cores.

Accepted by Astrophys. J.

Ice Grains in the Corona Australis Molecular Cloud

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We present medium-resolution spectra from 2.8 to 3.8 μm of 11 young association members and 8 background stars seen in the direction of the Corona Australis molecular cloud. Examination of the 3 μm water-ice absorption feature indicates that ice condensation has occurred and may account at least partially for the initial growth of anomalously large particles known to exist in the cloud. The durability of ice grains is strongly influenced by the environmental changes during early stellar evolution; the absorption feature is most prominent in embedded objects and diminishes among optically visible stars. As in other molecular clouds, the amount of ice is found to correlate linearly with the column density of grains along the line of sight, and there exists a threshold visual extinction only beyond which is the ice absorption detected. The threshold extinction in CrA is moderate, about 3-4 mag, similar to that found in Taurus.

Accepted by Astrophys. J.

Optical and Ultraviolet Observations of the star LkHα 264

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We present new ultraviolet and optical data for the classical T Tauri star LkHα 264. The most important features in the ultraviolet spectrum are identified and their fluxes are measured. These fluxes are then compared to the corresponding values in the Sun and in other T Tauri stars. Our time series of high resolution spectra for the regions of the Hα, He I λ5876 and Na I D lines includes data from seven consecutive nights. This allows the study of variability and provides hints to the location and characteristics of the regions producing the He I and the Hα lines. The data strongly suggests that most of the emission takes place in a relatively small and dense region, close to the star and undergoing a quite rapid expansion.

We are also able to measure the star's projected rotation velocity, $\approx 22 \pm 4 kms^{-1}$.

Accepted by M.N.R.A.S.

Sub-diffraction-limited infrared speckle observations of Z CMa - a 0.10" variable binary star

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[2] Steward Observatory,University of Arizona,Tucson, AZ 85721,USA
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Two-dimensional speckle interferometric observations at λ = 2.2 μ (K) obtained at the NOAO 4m telescope in December 1990 unambiguously show the pre-main sequence star Z CMa to be a binary with a separation of 0.10"+-0.01" (115 AU) at a position angle of 122 +- 2 °. Since the diffraction limit is λ/D=0.12", this result proves that two-dimensional speckle interferometry reaches sub-diffraction-limited resolution. Furthermore, photometric comparison with one-dimensional H and K band speckle data obtained at the Calar Alto 3.5m telescope between 1986 and 1989 reveals independent brightness variations of both components. Our data show no indication of a scattering halo, such

as could be expected in the presence of a massive circumbinary disk.

Accepted by Astron. Astrophys.

Effects of Magnetic Fields and Rotation on the Fragmentation of Filamentary Molecular Clouds: Comparison of the Theory with the Orion A Cloud

Tomoyuki Hanawa[1], Fumitaka Nakamura[2], Tomoaki Matsumoto[1], Takenori Nakano[2], Ken'ichi Tatematsu[2], Tomofumi Umemoto[2], Osamu Kameya[3], Naomi Hirano[4], Tetsuo Hasegawa[5], Norio Kaifu[6] and Satoshi Yamamoto[1]

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[6] National Astronomical Observatory, Mitaka, 181, Japan

We discuss the fragmentation of a filamentary molecular cloud on the basis of a magnetohydrodynamical stability analysis and the observations of the Orion A cloud with the Nobeyama 45 m telescope. Our model cloud has axial and helical magnetic fields and rotates around the axis. The dispersion relation for this cloud shows that the presence of magnetic field and/or rotation shortens the wavelength of the most unstable mode, i.e., the mean distance between the adjacent fragments, measured in units of the filament diameter. We compare the theoretical results with the observed clumpy structure of the filamentary Orion A cloud, and find that the sum of magnetic and centrifugal forces in the parent cloud was comparable with the pressure force (thermal and turbulent) and has had significant effects on the fragmentation. The rotation velocity of the filament measured in the ^{13}CO emission line is consistent with this result.

Accepted by Astrophys. J. Letters

The Formation and Evolution of Shocks in Stellar Jets From a Variable Wind

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Recent observations of jets from young stars indicate that the bright emission knots in these jets form at least in part because the jet varies in velocity and produces low velocity shocks in the flow. In this paper we use a 1-D fluid dynamics code that includes detailed cooling by line emission to investigate how shocks develop and evolve in a variable wind. Supersonic velocity perturbations in a jet always steepen and form a pair of shocks (called the 'forward' and 'reverse' shocks), which separate gradually as the flow evolves. Line emission from the hot gas between these shocks has a low excitation spectrum and large radial and tangential motions with respect to the exciting source, in agreement with observations of stellar jets.

The forward shock has a larger shock velocity than the reverse shock if a density enhancement accompanies the velocity perturbation. If there is no initial density perturbation then the forward and reverse shocks have equal shock velocities, and if the density perturbation is negative (corresponding to constant mass loss) then the reverse shock has a larger shock velocity. In all cases except the constant mass loss scenario the forward shock radiates more [S II] $\lambda\lambda$6716,6731 emission than the reverse shock because the material that encounters the reverse shock must first pass through a rarefaction wave.

The total [S II] emission produced by modest (~ 40 km s^{-1}) velocity perturbations rises rapidly as the shocks develop, and then either increases or decreases gradually (depending on the size of the perturbation) over tens of years. Models with strong magnetic fields have lower lines fluxes and lower excitation than models without fields, and the perturbations disperse more rapidly if a magnetic field is present. Knots from variable stellar jets show how much the stellar winds change over timescales of ~ 10 years.

Accepted by the Astrophysical Journal

New T Tauri Stars in Chamaeleon I and Chamaeleon II

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A new objective prism survey of the entire Chamaeleon I dark cloud and two-thirds of the Chamaeleon II cloud taken using a CCD detector with the Schmidt telescope at CTIO has uncovered 26 new Hα emission line objects that were missed by previous Hα plate surveys. The new Hα emission line objects have similar infrared colors and spatial distributions to the known T Tauri stars in these dark clouds, and could represent the very low mass end of the stellar population in these clouds or an older, less active component to the usual classical T Tauri star population. The present survey increases the total number of known young stars in both clouds by about 20%, a substantial increase important for studies of the initial mass function in these clouds.

The new Hα survey identified 70% of the total known YSO's in Cha I, compared with 35% for IRAS, and 25% from the Einstein X-ray survey. Ten of the new objects are weak-lined stars, with Hα equivalent widths less than 10Å. Overall, weak-lined T Tauri stars make up about half of the total population of young stars in the Chamaeleon I cloud, similar to the fraction of weak-lined stars known in the Taurus-Auriga cloud. I present coordinates, finding charts, and optical and infrared photometry of the new emission-line objects.

Accepted by Astron. J.

Infrared Images of the Young Cluster NGC 2264

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We present the initial results of an extensive infrared imaging survey of the young cluster NGC 2264 and a nearby galactic control field. A large portion of the cluster was imaged in each of the three standard near-infrared colors (J, H and K) with an infrared array camera. Similar observations were obtained of a large nearby region off the cluster and its associated molecular cloud. Comparison of these observations enabled us to estimate the size of the cluster population and investigate the nature of its members. In the region of the cluster surveyed at 2.2 μm (K), we detected more than 1,650 sources. After correcting for background/foreground field stars we find that the cluster contains 360 ($\pm$ 130) members. We find that the slope of the K luminosity function of the cluster is significantly steeper than that expected for a cluster of ZAMS stars and appears to flatten out or turn over at an apparent K magnitude of roughly 13.0-14.0. Both the slope and the turnover in the luminosity function can be modelled with an underlying cluster mass function which is similar to the Miller-Scalo or local field star IMF, provided that a mass-luminosity relation appropriate for pre-main sequence stars applies to the cluster population. From analysis of the JHK color-color diagrams of the cluster and control fields we find that approximately 170 sources observed toward the cluster have colors indicative of intrinsic excess infrared emission. Consequently, infrared excess stars appear to account for a relatively large fraction (50 $\pm$ 20 %) of the cluster membership. These stars have near-infrared colors similar to those of young emission-line stars such as classical T-Tauri stars and Herbig AeBe stars. Circumstellar disk models can account for the colors of most of these sources. That circumstellar disks are inferred for such a large fraction of the cluster membership argues for disk lifetimes which are at least as long as the age of the cluster (i.e., 5 x 10^6 years). Many of these stars are also characterized by relatively large amounts of extinction and may be partially embedded in the molecular cloud behind the cluster.

Accepted by The Astrophysical Journal

An Infrared Survey for Embedded Young Stars in the Perseus Molecular Cloud Complex

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We searched the Perseus Molecular Cloud Complex for isolated, embedded, and presumably young, stars using the survey data collected with the Infrared Astronomical Satellite (IRAS) and previously published visual extinction data.

Of the 23 source positions which satisfied both our IRAS color and visual extinction tests, we imaged 18 (the other 5 have been previously studied at 2μm) and identified the 2μm counterparts of 11 IRAS sources. We have estimated the luminosities and mean frequencies of these sources and compare these properties with a similarly-selected group of sources from the Taurus- Auriga cloud. We find that the isolated sources in Perseus Cloud have a slightly higher average luminosity and a distinctly lower average mean frequency than the sources in our Taurus sample. These results suggest that the Perseus Cloud is intermediate in its star forming character between the predominantly low mass star forming regions like Taurus, and those which are capable of producing very high mass stars, like the clouds in Orion.

Accepted by Ap. J.

Near-infrared speckle interferometry of LkHα 233

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Near-infrared speckle interferometry shows that LkHα 233 has a bright scattering halo about 1000 AU in size positioned symmetrically around the central star. This halo can be understood as inward continuation of the much more extended optical reflection nebula. The scattering particles in the halo must be larger than is typical for the interstellar medium. The intrinsic infrared colours of LkHα 233 are significantly altered by the subtraction of the halo from the system. The extinction to the central star appears to be underestimated because of the neglect of scattering.

Accepted by Astron. Astrophys.

Do the Spectral Energy Distributions of GK Tau and HK Tau Indicate the Presence of Planetary Companions?

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The continuum spectra of several T Tauri stars exhibit dips at mid-infrared wavelengths, an effect which we have interpreted in terms of discrete gaps in the circumstellar disks, resulting from the tidal effects of orbiting companion objects. In this paper, we discuss the interpretation of the spectral dips of three objects (DF Tau, GK Tau, and HK Tau) for which lunar occultation data are available. We present arguments against an alternate interpretation of the spectral dips (the "disk-shell" model), and use the lunar occultation data to constrain the properties of the inferred orbiting companions. In the case of DF Tau, the occultation data indicate a stellar-mass companion whose orbital radius is consistent with our inferred gap location. For GK Tau and HK Tau, no such companions are visible, which suggests that the companions responsible for the inferred gaps are substellar. In either case, the estimated gap width is not consistent with a single orbiting body, but is consistent with a group of planets or planetesimals.

Accepted by Astrophys. J. (Letters)

The Discovery of Two Herbig-Haro objects in the Small Dark Cloud D231.4-0.2 in Carina

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Two Herbig-Haro (HH) objects, designated HH 137 and 138, have been discovered toward eastern Carina in a small dark cloud. Their distance is probably 2.1 kpc, which is the second largest among known HH objects. Narrow-band CCD images have been obtained in the red [SII] lines, the Hα+[NII] emission and the adjacent continuum in order to investigate their morphology. HH 137 consists of many knots distributed roughly in the E-W direction, while HH 138 has fewer knots in a similar elongation. For two of the knots low-dispersion slit spectroscopy has also been performed and some physical parameters of the emission-line gas have been derived. The amount of interstellar extinction of these knots is the largest among HH objects having those known so far. HH 138 is located roughly on the extension of the axis of HH 137, but it is not clear whether they make a physically associated HH pair. The westernmost knot of HH 137 appears to correspond to the working surface of the outflow, and one of the konts, which is bright in Hα+[NII], is probably the Mach disk. There is no IRAS point source which can be identified as the exciting star for HH 137 and

138.

Accepted by Mon. Not. Royal Astron. Soc.

The molecular environment of S106 IR

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Millimetre and submillimetre images of the bipolar nebula S106 are presented which resolve the structure of the circumstellar material around the exciting star S106 IR. The previously unresolved 'dust bar' is seen to break up into a number of sources: there is no evidence for a smooth disc about the star. There is a bright, previously undetected far-infrared point source in the dust lane which is not detected at 20 μm, suggesting it is an extremely embedded object of moderate luminosity (30–1000 $L_\odot$); this object may be a *very young* protostellar companion to S106 IR.

Maps of the C18O $J = 1 \rightarrow 0$ and CS $J = 3 \rightarrow 2$ emission are presented, and these correlate well with the continuum maps. Consistent column densities can be derived from the dust and line emission using standard molecular abundances and modest dust temperatures (about 50 K) suggesting that most of the circumstellar dust and gas is *warm* and that no significant molecular depletion has occurred.

We have also mapped the *hot* circumstellar gas as traced by the CO $J = 6 \rightarrow 5$ line, and we derive a lower limit to the temperature of this component of 165 K, and find that its mass is > 0.05 of the total molecular gas mass. This component is clumpy on 8-arcsec scales, has the same linewidth as the lower lying CO transitions, and is closely associated with the warm (≈ 50 K) molecular gas in the dust lane traced by the adjacent continuum radiation; these features are consistent with a model in which the hot and warm gas are approximately co-spatial and are heated from within the dust ring.

Accepted by Monthly Notices of the Royal Astronomical Society

A Circumstellar Molecular Gas Structure Associated with the Massive Young Star Cepheus A-HW 2

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We report the detection via VLA-D observations of ammonia of a circumstellar high-density molecular gas structure toward the massive young star related to the object Cepheus A-HW 2, a firm candidate for the powering source of the high-velocity molecular outflow in the region. This structure has a deconvolved angular size of $3.''3 \times 2.''3$ (p.a. = 22°), or 2400×1700 AU at a distance of 725 pc. For this circumstellar molecular gas structure we derive an average column density $N(H_2) \simeq 1 \times 10^{24} [\frac{X_{NH_3}}{10^{-8}}]$ cm^{-2}, a volume density $n(H_2) \simeq 3 \times 10^{7} [\frac{X_{NH_3}}{10^{-8}}]$ cm^{-3}, and a mass $M(H_2) \simeq 2 [\frac{X_{NH_3}}{10^{-8}}]$ $M_\odot$. The ammonia emission shows velocity variations of ~ 4 km s^{-1} across the condensation. HW 2 was previously reported to be a double radio source, separated by $\sim 0.''2$ (or 150 AU) with p.a. $\simeq 30°$–$40°$. We suggest that the circumstellar molecular gas structure could be related to the circumstellar disk previously suggested from infrared, H_2O, and OH maser observations. We consider as a plausible scenario that the double radio continuum source of HW 2 could represent the ionized inner part of the circumstellar disk, in the same way as proposed to explain the double radio source in L1551. The observed motions in the circumstellar molecular gas can be produced by bound motions (e.g., infall or rotation) around a central mass of $\sim$ 10–20 $M_\odot$ (B0.5 V star or earlier).

Accepted by Astrophys. J. Letters

Meetings

The Cold Universe (XVIIIth Rencontres de Moriond)

Dates: March 13 – March 20, 1993

Venue: Les Arcs, Savoie, France

International Advisory Committee:
C. Bertout (Grenoble), Y. Fukui (Nagoya), R. Gusten (Bonn), M. Hauser (Goddard), R. Hills (Cambridge-GB), E. Khachikian (Byurakan), C.J. Lada (co-Chair, Cambridge-US), P. Lena (Meudon), T. Montmerle (co-Chair, Saclay) A. Natta (Florence), P. Planesas (Yebes), J.-L. Puget (Orsay), L.-F. Rodriguez (Mexico), D. Sanders (Hawaii), S. Stahler (Berkeley), R. Terlevitch (Cambridge-GB)

Program Committee:
Ph. Andre (Saclay), J.-P. Chieze (Bruyeres-le-Chatel), F. Genova (Paris), C.J. Lada (Cambridge-US), P.-O. Lagage (Saclay), F. Mirabel (Saclay), A. Omont (Paris), D. Rouan (Meudon), J. Tran Thanh Van (Orsay), S. Volonte (Paris)

Outline of Scientific program:

1) Introductory reviews: physics and chemistry of the ISM
a) Interstellar dust; b) Interstellar gas; c) Shock chemistry; d) Cloud collisions and shocks; e) Diagnostics and goals for future experiments; f) Dust in various astrophysical environments.

2) Circumstellar material
a) Evidence for circumstellar disks; b) Bipolar flows, winds, and jets; c) FU Orionis stars; d) Theories of outflows

3) Origin of stars and planets
a) Star formation and early evolution; b) Embedded stellar populations; c) Ae/Be stars; d) Disk stability and conditions for planet formation; e) Birth and evolution of giant planets

4) Molecular clouds
a) Large-scale structure and dynamics; b) Small-scale structure; c) Stability and magnetic processes; d) Unbiased surveys of cloud cores; e) Protostellar condensations; f) Brown dwarfs

5) Large-scale cold ISM: Galactic and extragalactic
a) Structure and evolution of the ISM; b) Cold ISM turbulence and star formation; c) Diffuse galactic component; d) Milky Way results from COBE; e) Molecules in nearby galaxies; f) Dense gas in nearby galaxy nuclei; g) Dust in nearby galaxies; h) HI in clusters of galaxies; i) Extragalactic masers

6) Starbursts and luminous objects
a) Star formation in normal galaxies; b) Starbursts and colliding galaxies; c) Luminous objects at high z; d) High-z IR galaxies

7) Origin of galaxies
a) Primeval galaxies: observations; b) Primeval galaxies: theory; c) Lyman alpha forest; d) Molecular gas in high-z galaxies; e) Chemical evolution at high z

8) Projects in space and on the ground
a) 2-micron surveys; b) mm detectors and interferometers; c) near-IR adaptive optics; d) ISO and other IR from space; e) submm astronomy from balloons and from space; f) new mm receivers

For more information, contact, and give your postal and e-mail addresses to:

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The First Symposium on the Infrared Cirrus and Diffuse Interstellar Clouds

Dates: 7 – 9 April 1993

Venue: The Hotel Park Tucson, Tucson, Arizona, USA

Local Organizing Committee:
Roc Cutri (Steward Obs), William Latter (NRAO)

Scientific Organizing Committee:
Lou Allamandola (NASA/Ames), Chas Beichman (IPAC), John Black (Steward Obs), Francois Boulanger (L'Ecole Normale), Ewine van Dishoeck (Leiden), Gillian Knapp (Princeton U.), Frank Low (Steward Obs), Peter Martin (CITA), Kristen Sellgren (Ohio St. U), Barry Turner (NRAO)

The aim of this meeting is to provide for the first time a forum for the discussion of the diffuse cloud component of the interstellar medium. Topics to be discussed will include:

Day 1: Phenomenology of the Cirrus and Diffuse Clouds

UV, Visible and IR Absorption Line Studies - UV and Visible Extinction and Emission - HI, Molecular and Infrared Surveys - Impact of Cirrus and Diffuse Clouds on Ground- and Space-Based Observations

Day 2: Composition and Chemistry of the Cirrus and Diffuse Clouds

Large and Small Dust Grains and Large Molecules - Atomic, Molecular and Ionized Gas - Cirrus and Diffuse Cloud Chemistry - Cirrus and Diffuse Clouds as Probes of the Interstellar Radiation Field

Day 3: Energetics and Evolution of the Cirrus and Diffuse Clouds

General Energy Budget - Cirrus and Diffuse Cloud Dynamics - Dynamical Evolution of the Cirrus and Diffuse Clouds - Origin and Relationship to the Dense Interstellar Medium

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2^{nd} Köln - Zermatt Symposium on
The Physics and Chemistry of Interstellar Molecular Clouds

Mm, Sub-mm, and IR-Observations in Astrophysics

Dates: 21 - 24 September 1993

Venue: Zermatt, Switzerland

The scope of the meeting is to review the most recent scientific and technological developments in the field of millimeter, submillimeter, and infrared astrophysics, with special emphasis on the development of the last five years which have elapsed since the 1^{st} Köln - Zermatt Symposium

The symposium will feature invited lectures, contributed lectures of 10-15 min. length, and poster sessions, as well as a visit to the nearby KOSMA-Observatory, home of the 3-m telescope of the University of Cologne.

More information can be obtained from:
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